Upper Missouri River Basin
March 2016 Calendar Year Runoff Forecast
March 4, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

February 2016 Calendar Year Runoff

February 2016 Missouri River runoff was 1.9 MAF (170% of average) above Sioux City, IA (Upper Basin). February 2016 runoff above Gavins Point Dam was 1.6 MAF (159% of average). Warmer-than-normal temperatures resulted in the melting of nearly the entire plains snowpack, which resulted in above average runoff in February. Much of the runoff that occurred in February 2016 would be expected to occur in March and April in a year with more typical temperatures.

2016 Calendar Year Forecast Synopsis

The February 1 forecast for the 2016 Missouri River Basin runoff above Sioux City, IA (Upper Basin) is **21.6 MAF (85% of average)**. Runoff above Gavins Point Dam is forecast to be **19.3 MAF (83% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 10 months, the range of expected inflow is quite large and ranges from the 29.0 MAF upper basic forecast to the 15.1 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to “bracket” the range of expected runoff given much wetter or drier conditions, respectively. Given that 10 months are being forecasted for this March 1 forecast (2 months observed/10 months forecast), the range of wetter than normal (upper basic) and lower than normal (lower basic) is attributed to all 6 reaches for 10 months. The result is a large range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for March 1, 2016 (**Figure 1**), when compared to the drought monitor for January 26, 2016 (**Figure 2**), shows a slight increase in areal extent of Abnormally Dry (D0) and Moderate Drought (D1) conditions in the upper Basin, primarily in western North Dakota. There has been a slight decrease of drought severity in western Montana. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought will persist in western Montana and south-central North Dakota. Drought conditions are likely to ease in south-central Montana and north-central Wyoming through the end of May 2016.

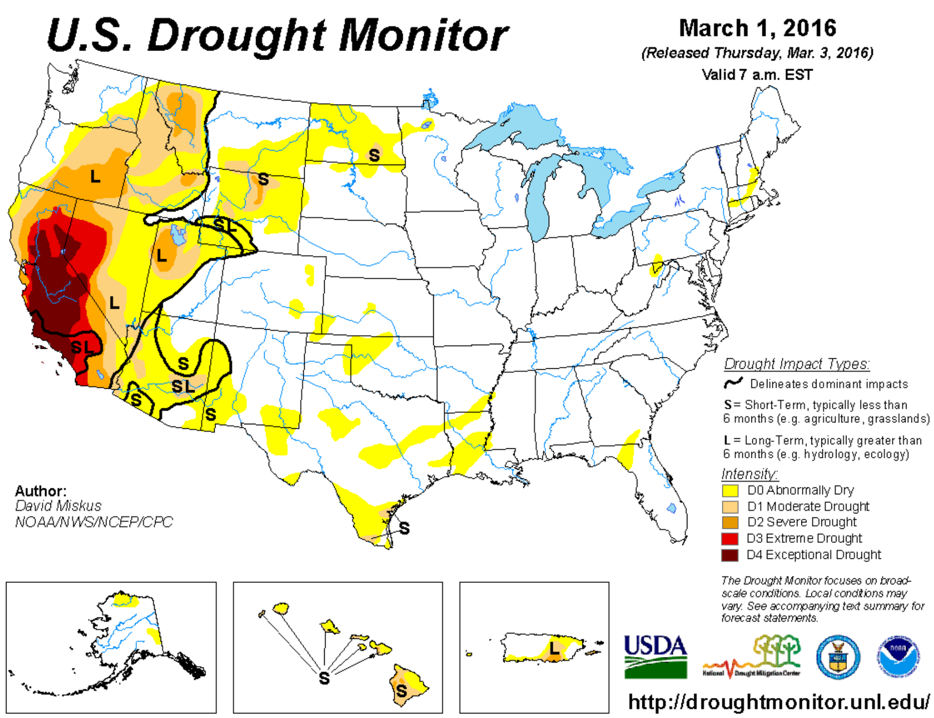


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for February 23, 2016.

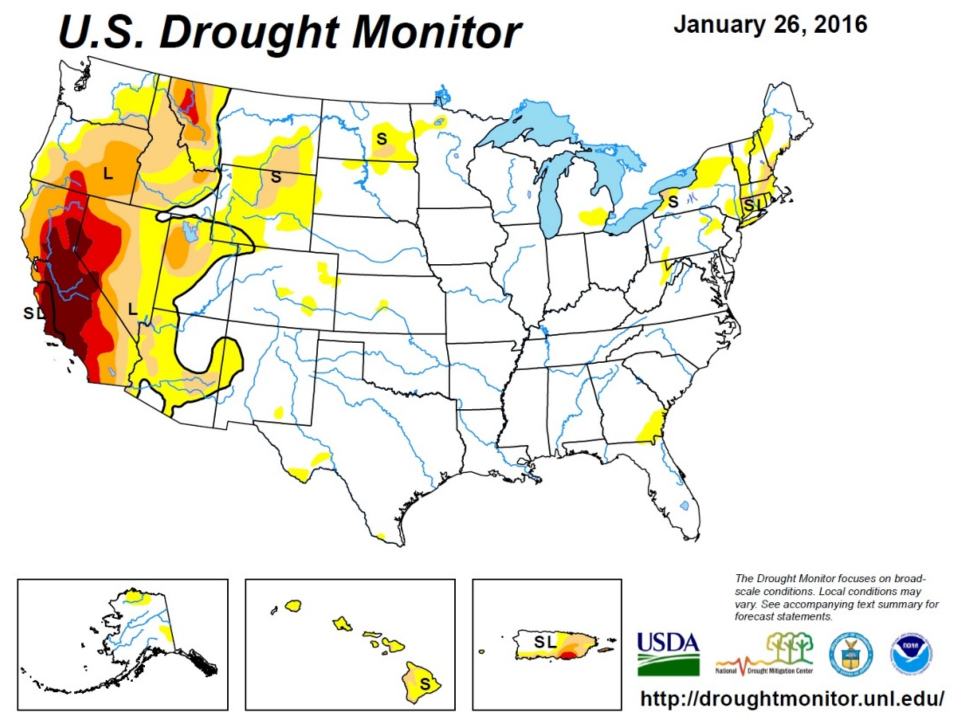


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for January 26, 2016.

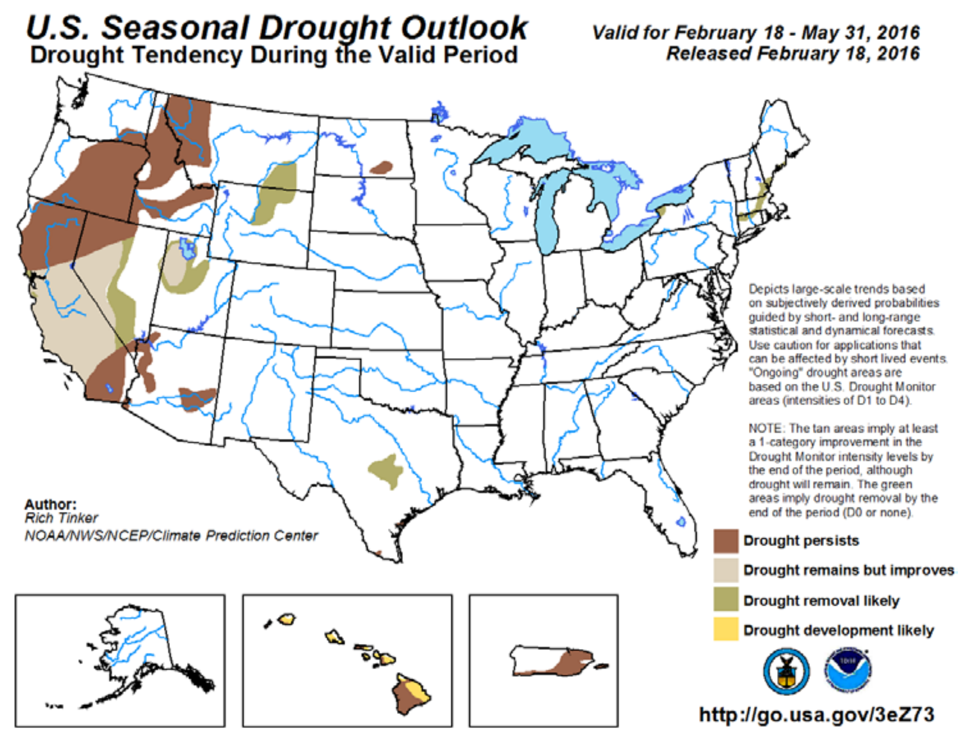


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

February precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). Precipitation amounts in the left image of Figure 4 generally ranged from 0.1 to 1.5 inches. The greatest amounts of February precipitation occurred in northwest Kansas extending northeastward into northeast Nebraska and northwest Iowa. As a percent of normal in the right image of Figure 4, precipitation was generally below normal in central and western Montana and much of Wyoming, as well as much of eastern Kansas and Missouri. Above normal areas occurred in eastern Montana, portions of South Dakota and a broad band from eastern Colorado extending northeast towards northwestern Iowa.

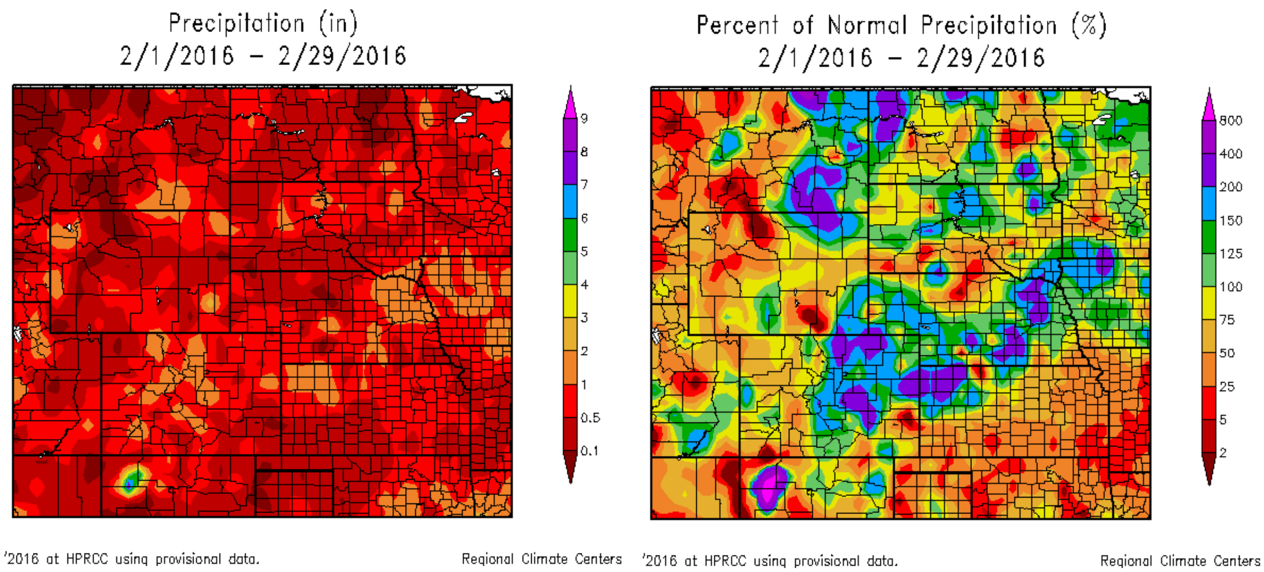


Figure 4. February 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

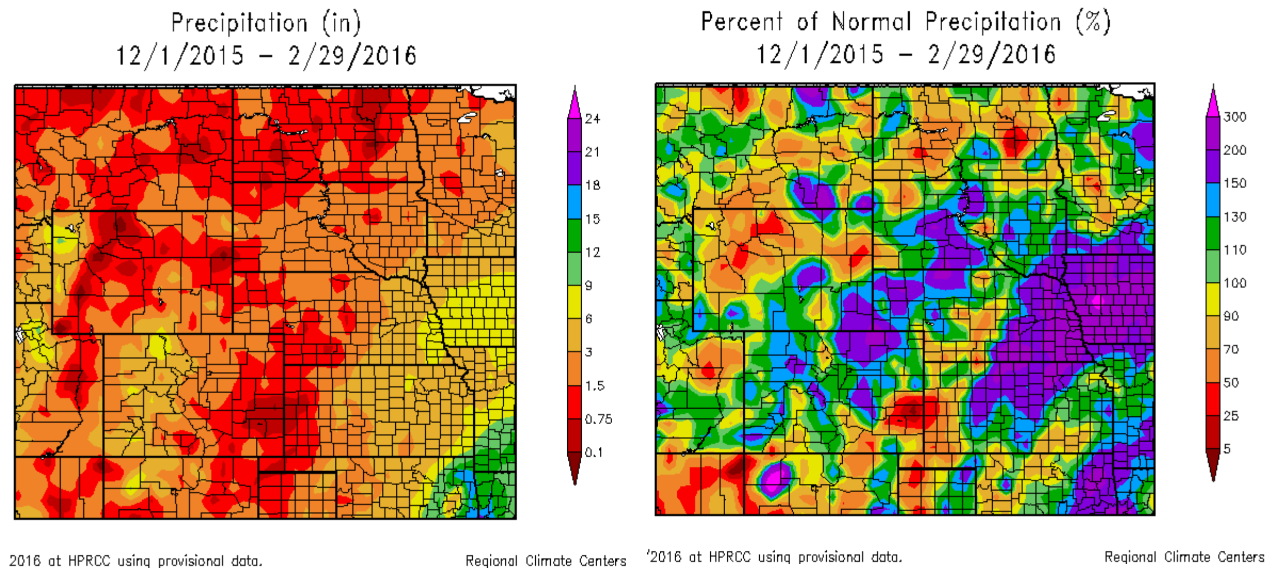


Figure 5. December 2015-February 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

December 2015-January-February 2016 precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a generally dry pattern extending from northwest Wyoming through northeastern North Dakota, as well as portions of central Montana. In contrast, a wet or above normal precipitation pattern has been prevalent in portions of western and eastern Montana, from northeast Colorado extending into central South Dakota, and in most of the lower Basin. These areas received greater than 150 percent of normal precipitation since December 1, 2015.

Temperature

February temperature departures from normal are shown in **Figure 6** in degrees Fahrenheit (deg F). February temperature departures in the Upper Basin were generally above normal ranging from 6 to 12 deg F. Temperatures were within 2 deg F of normal in small areas scattered across eastern Nebraska and western Iowa. Three-month (December-January-February) temperature departures are shown in **Figure 6**. The map indicates a very similar above normal pattern of temperatures across much of the Missouri Basin, particularly in the Northern Plains and lower Basin. Temperatures have been near normal to slightly below normal in the Rocky Mountains and through portions of western Nebraska and southwestern South Dakota.

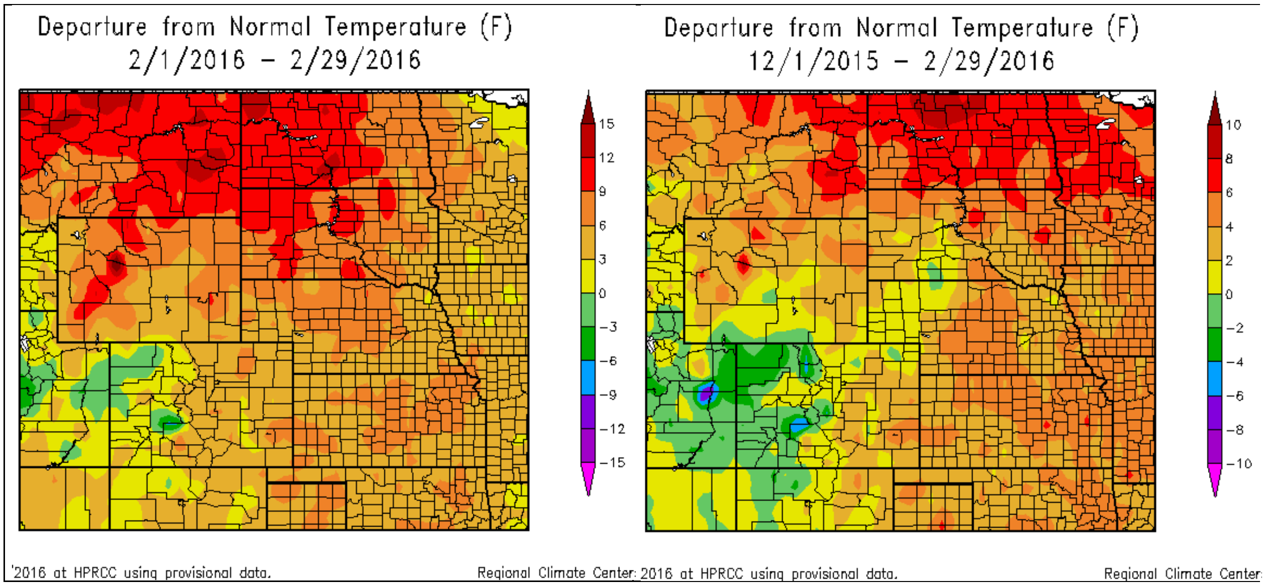


Figure 6. February 2016 and December 2015-February 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on February 26, 2016 for the top 1 meter of the modeled soil column. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above normal soil moisture conditions are present throughout much of the Upper Basin, though there are dry areas including north-central Wyoming, eastern Montana, and eastern North Dakota, as well as portions of eastern Kansas and western Missouri. Wet soil moisture conditions (greater than 90th percentile moisture) are indicated in north central Montana, eastern Nebraska, and western Iowa.

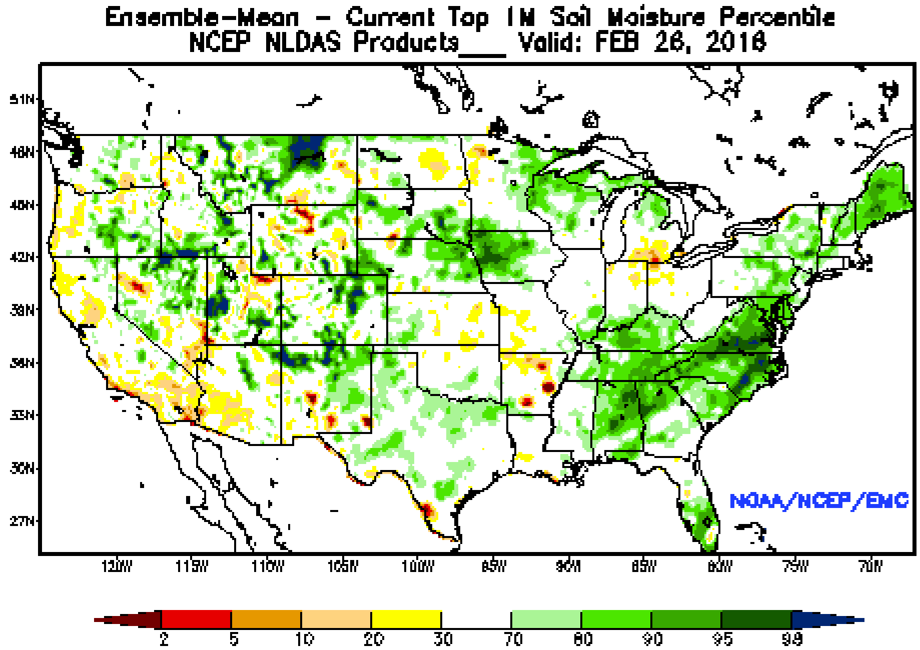


Figure 7. Top 1-Meter Soil Moisture Percentile on February 26, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Frost Conditions

Soil frost acts as a semi-impervious layer to snowmelt or precipitation infiltration into the soil. **Figure 8** shows depth of frost penetration at National Weather Service (NWS) Warning Forecast Office (WFO) locations in the Missouri Basin as of February 29, 2016. While some frost depth measurements are missing, measurements indicate soils are frozen at variable depths. Frost depths at Aberdeen and Bismarck are 24 inches and 25 inches, respectively. In much of the remainder of the Basin, most depth measurements report as M (missing) or 0 inches.

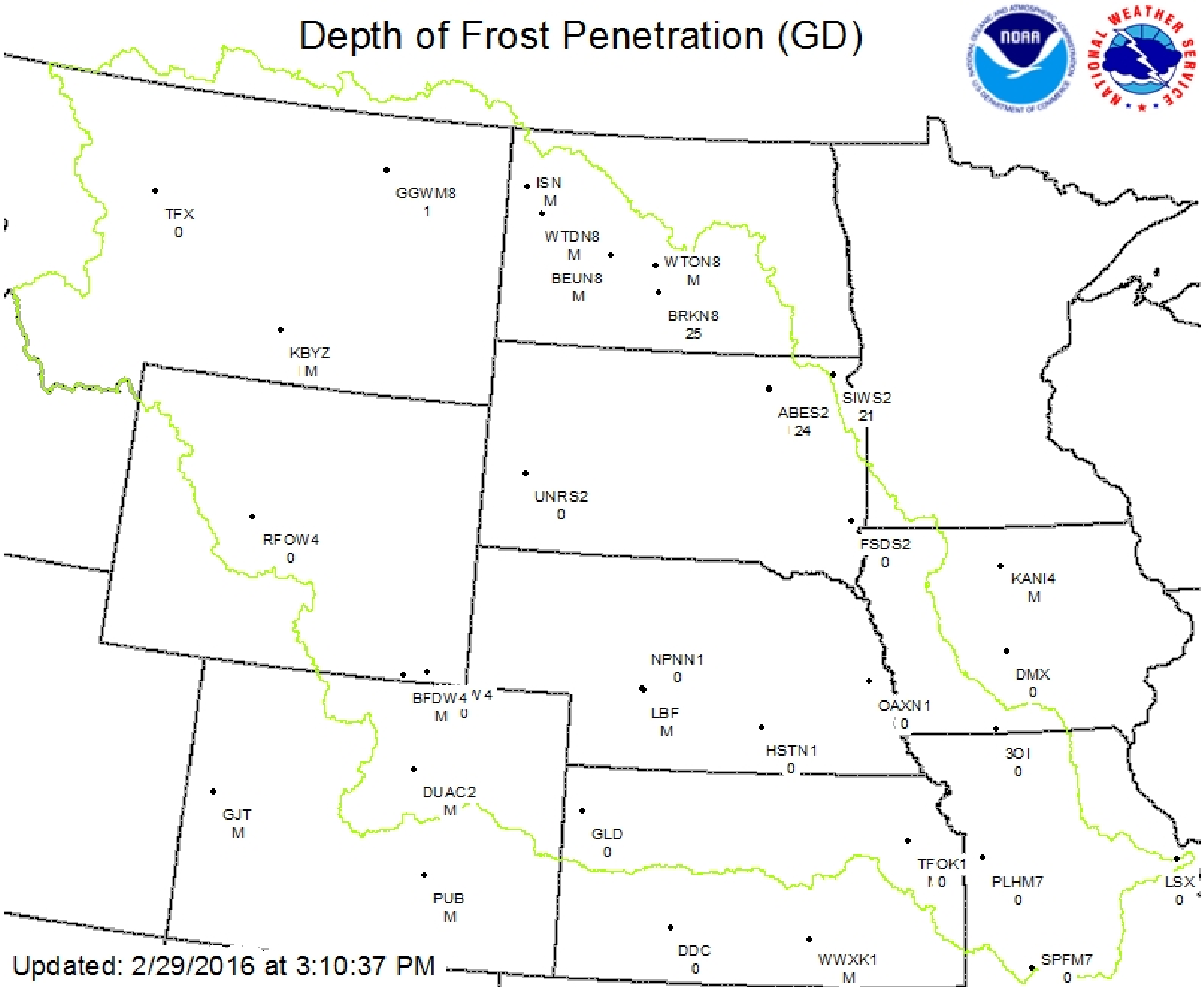


Figure 8. Measured frost depth (inches) at NWS WFO offices as of February 29, 2016. Source: NWS MBRFC. http://www.crh.noaa.gov/mbrfc

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 9**. These conditions are based on the ranking of the March 2, 2016 daily streamflow versus the historical record of streamflow for that date. Where streams are currently not influenced by ice formation along the mainstem of the Missouri River below Gavins Point Dam, streamflow conditions continue to be "Normal" (25^{th}-75^{th} percentile), "Above normal" (76^{th} – 90^{th} percentile) or "Much above normal" (greater than the 90^{th} percentile). In the Upper Basin, a majority of stations have no classification because the current stream gages are either ice-affected or the historical record is ice-affected. The few stations in the Upper Basin that are reporting indicate streamflow conditions, particularly in Montana and Wyoming, are mostly "Normal" (25^{th}-75^{th} percentile) to "Below normal" (10^{th}-24^{th} percentile), although some locations report "Above Normal" (76^{th} – 90^{th} percentile).

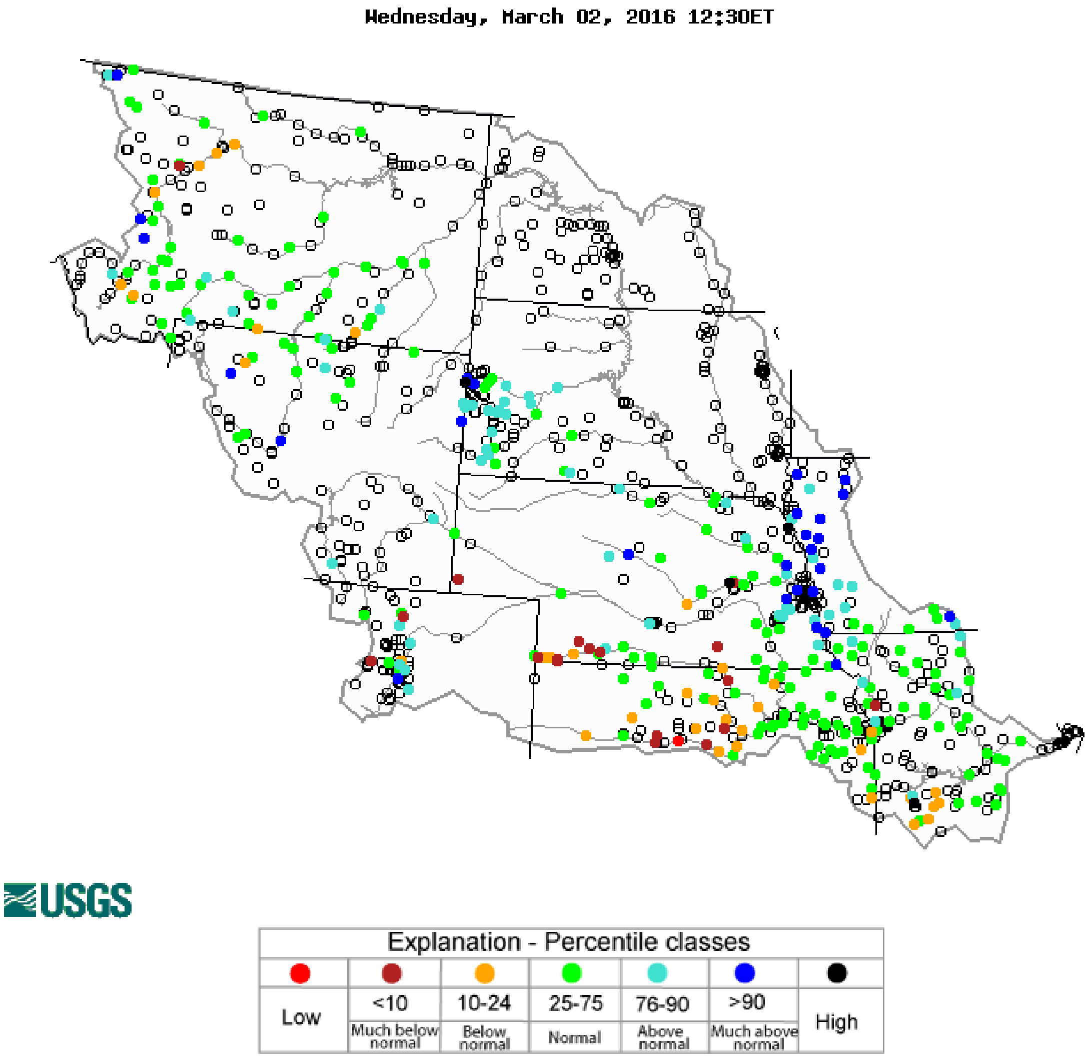


Figure 9. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of March 2, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks.

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 10**) as of March 1, 2016 the only plains snow cover remains in a band from north-central and northeastern Montana through much of South Dakota extending into northern Iowa. According to Corps cooperative snow observers prior to the end-of-month snow storm, the remaining snow was either in drifts or in ditches. SWE measured prior to end of month by the observers in the upper James River basin in North Dakota was 0.6 inches; all other observers were reporting 0.0 inches SWE.

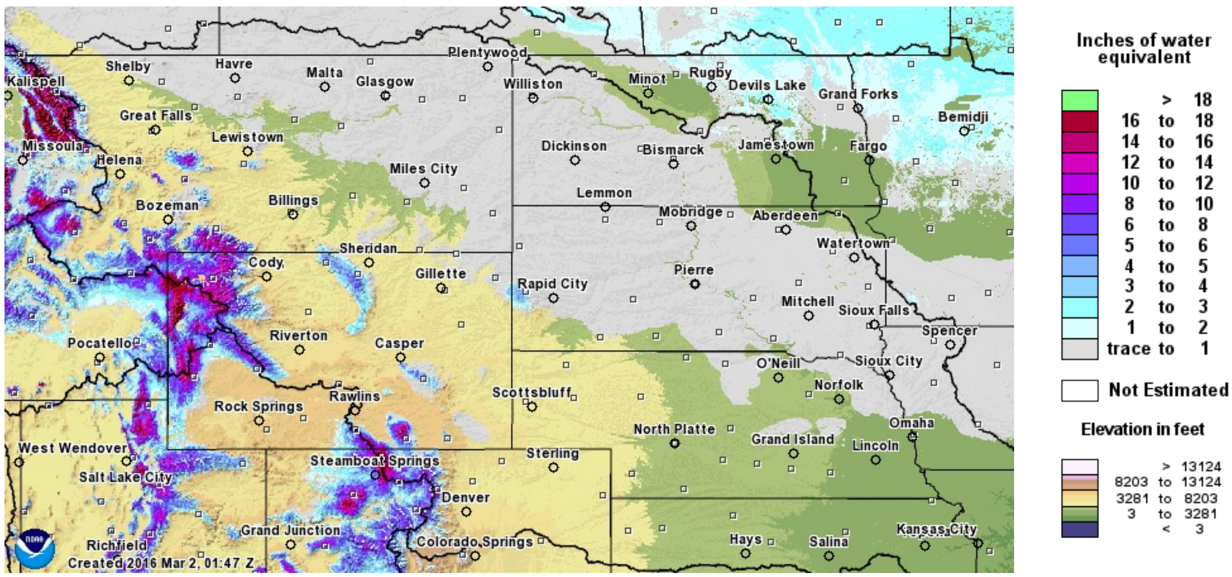


Figure 10. March 1, 2016 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Using the MRBWMD snowpack classification method, plains snowpack for the March 1, 2016 runoff forecast was classified according to the terminology listed in **Table 1**. A "Light" snowpack indicates snow cover that is above the median SWE, and a "Moderate" snowpack is greater than "Light". "Average" basin conditions indicate snowpack is less than "Light" with no measureable snow accumulations. March-April runoff in "Average" conditions is expected to be below or near long term average runoff. Runoff resulting from "Light" and "Moderate" snowpack accumulations is expected to be above long term average March-April runoff.

Table 1. Plains snowpack classification for the March 1, 2016 runoff forecast.

Reservoir Reach	Plains Snowpack Classification
Above Fort Peck	None-Average
Fort Peck to Garrison	None-Average
Garrison to Oahe	None-Average
Oahe to Fort Randall	None-Average
Fort Randall to Gavins Point	None-Average
Gavins Point to Sioux City	None-Average

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-July runoff period, about 50% of the annual runoff enters the mainstem system as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see below-average runoff from a below-average mountain snowpack this year due to soil moisture conditions ranging from drier than normal to wetter than normal.

Figure 11 includes time series plots of the average mountain SWE beginning on October 1, 2015 based on the NRCS SNOTEL gages for the basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of **February 29, 2016**, the Corps of Engineers computed an average mountain SWE in the **Fort Peck reservoir reach of 11.5 inches, which is 89% of average** based on the 1981-2010 average SWE for the Fort Peck reach. In the **reservoir reach between Fort Peck Dam and Garrison Dam**, the Corps computed an average mountain SWE of **8.2 inches, which is 75% of average** based on the 1981-2010 average SWE for the Garrison reach. Normally by March 1, about 80% of the peak snow accumulation has occurred in the mountains.

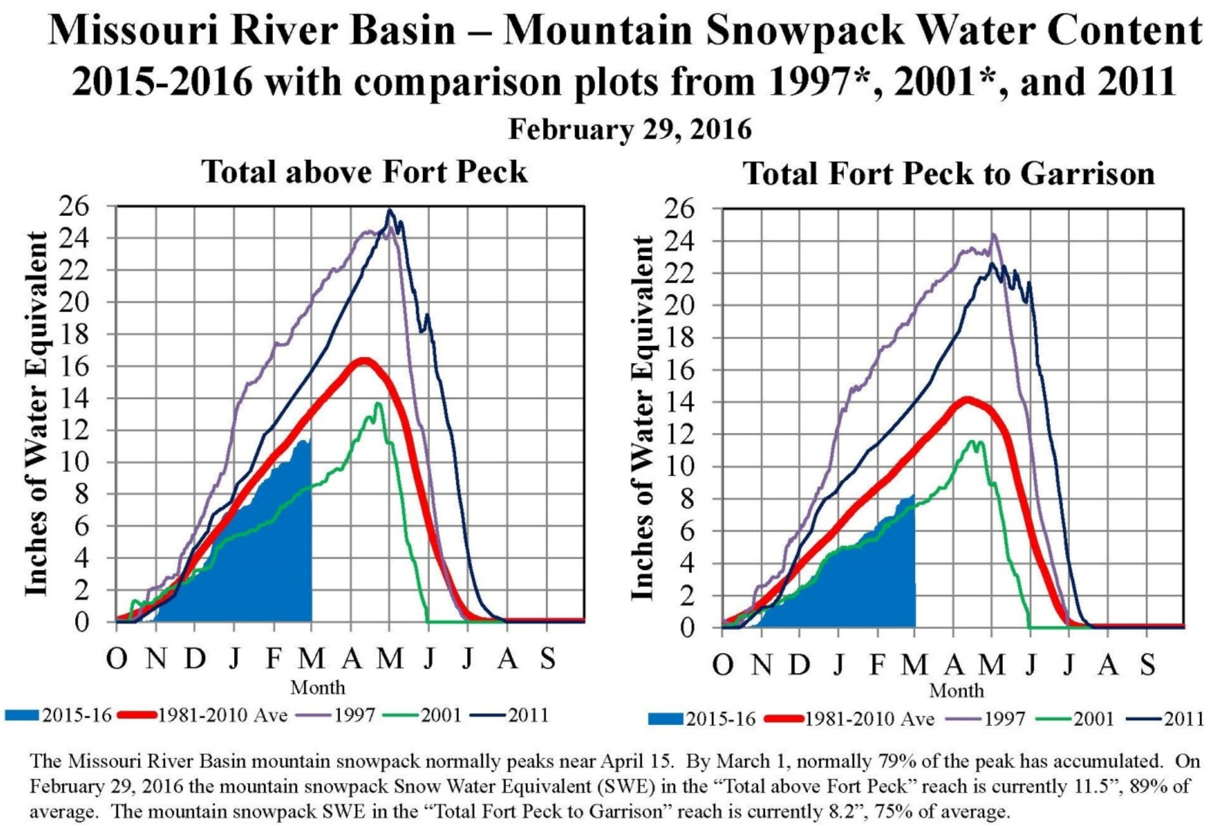


Figure 11. Mountain snowpack water content on February 29, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update[1] on February 29, 2016, "***El Niño conditions are present. Positive equatorial sea surface temperature (SST) anomalies continue across most of the Pacific Ocean. A transition to ENSO-neutral is likely during late Northern Hemisphere spring or early summer 2016, with a possible transition to La Niña conditions during the fall."***

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the El Niño climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin. The possible impacts of El Niño have been factored into the CPC climate outlooks described below.

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for March 2016 (**Figure 12**) indicates an increased probability for above normal temperatures over the entire Missouri Basin with the exception of western Kansas, which has an equal chance of above- or below-normal temperatures. Probabilities for above normal temperatures range from a greater than 60% chance temperatures will be above normal in northern North Dakota to a 33.3% to 40% chance across the Lower Basin. With regard to precipitation, there is a greater than 40% chance precipitation will be below normal in north-central Montana, and a 33.3% to 40% chance for below-normal precipitation in most of the rest of Montana. There are increased chances for above-normal precipitation in Colorado, southeastern Wyoming, Nebraska, southern South Dakota, and Kansas.

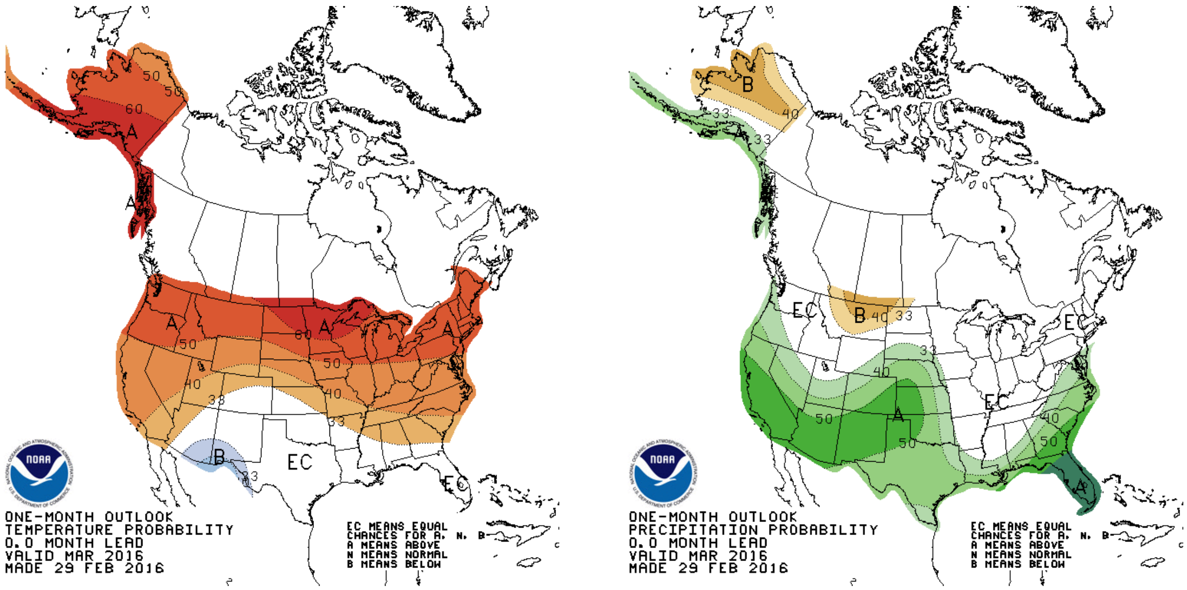


Figure 12. CPC March 2016 temperature and precipitation outlooks.

The March-April-May 2016 temperature outlook (**Figure 13**) indicates a slight reduction in the area of increased chances for above normal temperatures through the end of May. The March-April-May precipitation outlook also indicates a reduction in the area of increased chances for below-normal precipitation for nearly all of Montana as well as a reduction in the area of increased chances for above normal precipitation, although more of Colorado and Wyoming will see an increased chance for above-normal precipitation. The June-July-August 2016 CPC temperature outlook (**Figure 14**) indicates there are increased chances for above-normal temperatures across the entire Missouri Basin. In terms of precipitation, there are equal chances for above- and below-normal precipitation throughout the entire Missouri Basin.

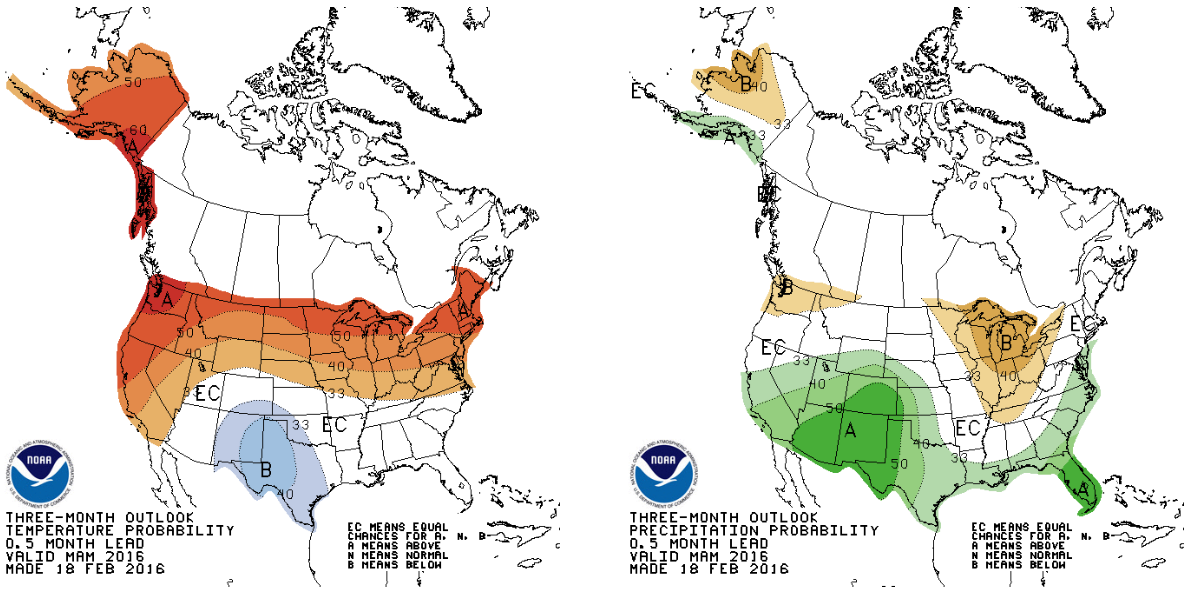


Figure 13. CPC March-April-May 2016 temperature and precipitation outlooks.

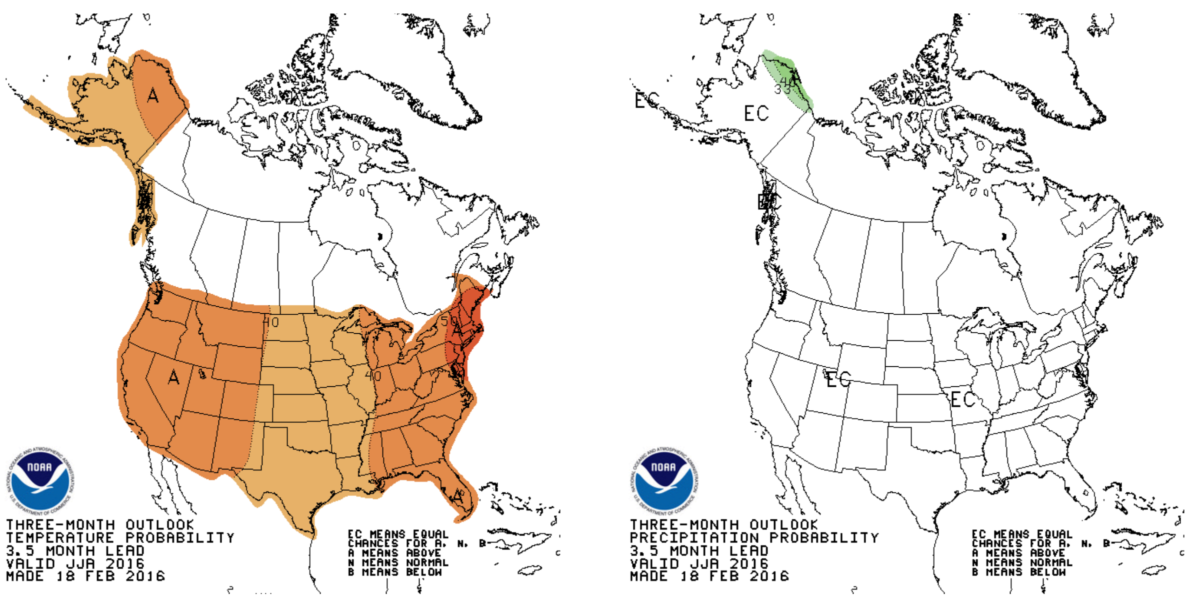


Figure 14. CPC June-July-August 2016 temperature and precipitation outlooks.

During the September-October-November 2016 period (**Figure 15**) CPC outlooks indicate increased chances for above-normal temperatures across the entire Missouri Basin, and equal chances for above-normal, normal and below-normal precipitation, except for Colorado and western Kansas, where there is an increased chance for below-normal precipitation. The December 2016-January-February 2017 period (**Figure 16**) outlook indicates increased chances for below-normal temperatures in the Northern Rockies and plains. With regard to precipitation, the **Figure 18** outlook indicates there is an increased chance for above-normal precipitation in the Northern Rockies and equal chances for much of the remaining Missouri Basin, with the exception of Colorado and Kansas, which indicates an increased chance for below-normal precipitation.

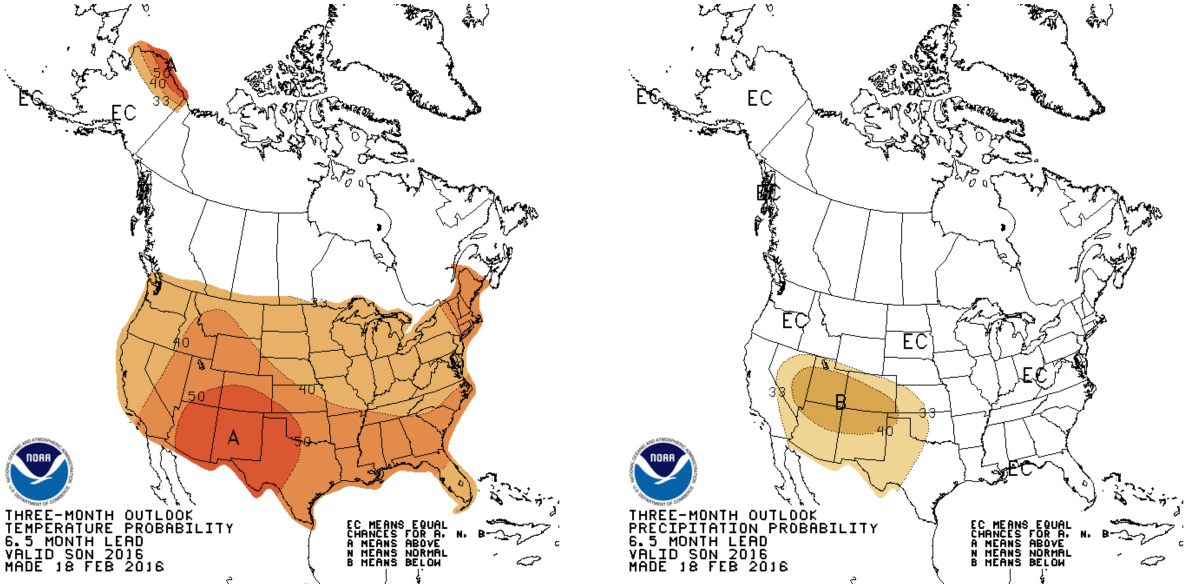


Figure 15. CPC September-October-November 2016 temperature and precipitation outlooks.

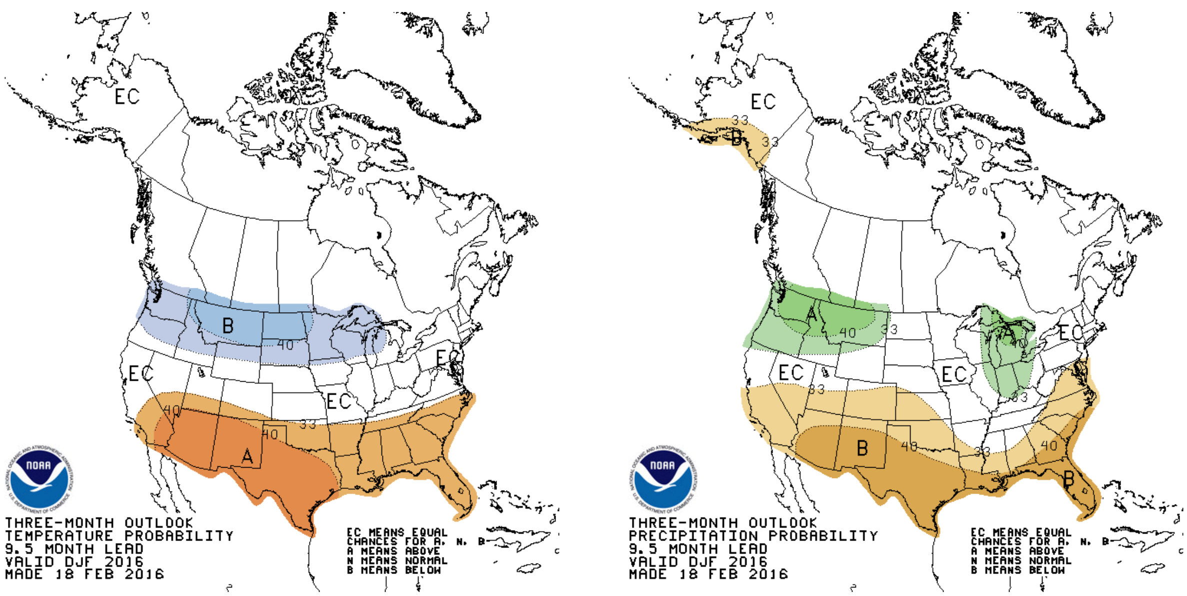
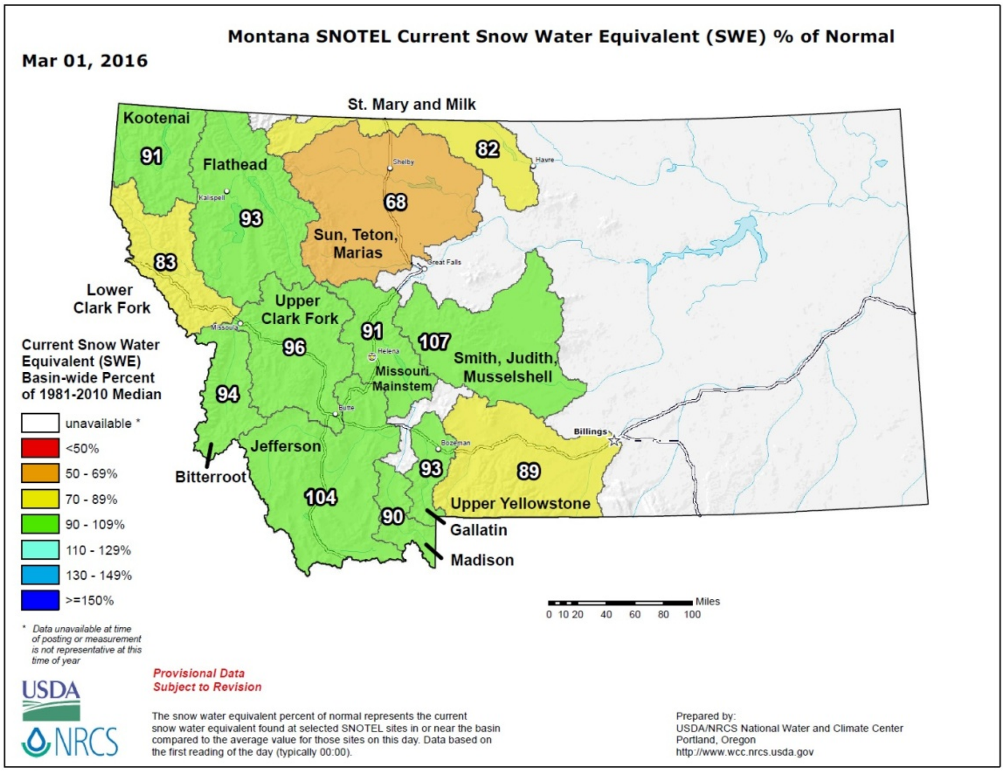


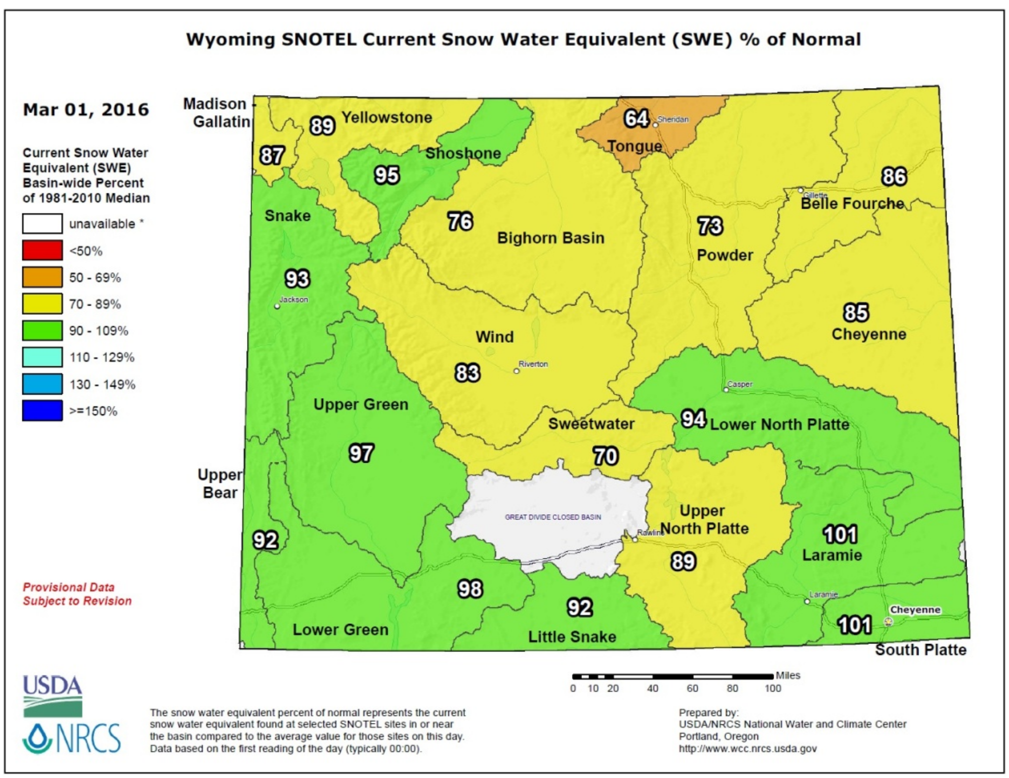
Figure 16. CPC December 2016-January-February 2017 temperature and precipitation outlooks.

March 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **21.6 MAF**, **85% of average**. Once again, we expect that the warmer-than-normal temperatures that are forecast over the next three months will lead to melt reduced runoff from rainfall. Runoff is forecast to be below average in March and April, due to early plains snowmelt and a lack of remaining plains snowpack. The below-average mountain snowpack will likely lead to below-average May-June-July runoff in the Fort Peck and Garrison reaches.

Additional Figures





USDA NRCS National Water & Climate Center
* - DATA CURRENT AS OF: March 03, 2016 04:40:13 PM
- Based on March 01, 2016 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow	APR-JUL	86	89	101	92	80	71	97
	APR-SEP	100	89	117	107	93	83	112
St. Mary R at Int'l Boundary (2)	APR-JUL	380	87	480	420	340	280	435
	APR-SEP	435	86	540	475	395	330	505
Lima Reservoir Inflow (2)	APR-JUL	68	83	102	82	54	34	82
	APR-SEP	74	83	115	90	58	33	89
Clark Canyon Reservoir Inflow (2)	APR-JUL	82	81	167	116	48	21	101
	APR-SEP	100	83	193	138	62	7.2	120
Jefferson R nr Three Forks (2)	APR-JUL	720	97	1150	890	550	295	740
	APR-SEP	780	98	1250	970	590	310	800
Hebgen Reservoir Inflow (2)	APR-JUL	305	82	370	330	275	235	370
	APR-SEP	385	82	465	420	355	310	470
Ennis Reservoir Inflow (2)	APR-JUL	525	84	665	580	470	385	625
	APR-SEP	660	85	825	725	595	495	775
Missouri R at Toston (2)	APR-JUL	1610	90	2300	1890	1330	915	1790
	APR-SEP	1860	90	2670	2190	1530	1050	2070
Smith R bl Eagle Ck (2)	APR-JUL	107	101	163	130	85	51	106
	APR-SEP	117	101	183	144	90	51	116
Gibson Reservoir Inflow (2)	APR-JUL	275	70	380	315	235	171	395
	APR-SEP	310	70	420	355	265	199	440
Marias R nr Shelby (2)	APR-JUL	205	59	385	280	133	27	345
	APR-SEP	210	58	400	285	131	16.3	360
Milk R at Western Crossing	MAR-SEP	25	76	53	38	15.4	6.8	33*

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	APR-JUL	48	81	57	52	44	39	59
	APR-SEP	62	84	74	67	57	50	74
Wind R ab Bull Lake Ck (2)	APR-JUL	380	84	490	425	335	270	455
	APR-SEP	400	82	530	450	350	270	490
Bull Lake Ck nr Lenore	APR-JUL	116	83	147	128	104	85	139
	APR-SEP	141	83	179	157	125	103	169
Boysen Reservoir Inflow (2)	APR-JUL	400	66	785	555	245	14.9	610
	APR-SEP	425	64	855	600	250	15.0	665
Greybull R nr Meeteetse	APR-JUL	116	89	153	131	101	79	131
	APR-SEP	155	88	205	174	136	107	177
Shell Ck nr Shell	APR-JUL	40	73	55	46	34	25	55
	APR-SEP	50	76	67	57	43	33	66
Bighorn R at Kane (2)	APR-JUL	535	64	1060	750	325	17.1	840
	APR-SEP	545	60	1110	775	315	15.0	905
NF Shoshone R at Wapiti	APR-JUL	425	92	525	465	385	325	460
	APR-SEP	475	92	585	520	430	365	515
SF Shoshone R nr Valley	APR-JUL	205	95	250	225	186	159	215
	APR-SEP	235	96	285	255	215	183	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	645	96	800	705	580	485	675
	APR-SEP	705	95	885	780	635	530	745
Bighorn R nr St. Xavier (2)	APR-JUL	1040	75	1680	1300	785	410	1380
	APR-SEP	1060	73	1770	1340	770	345	1460
Little Bighorn R nr Hardin	APR-JUL	50	51	97	69	31	3.0	98

	APR-SEP	58	52	110	79	37	5.8	111
Tongue R nr Dayton (2)	APR-JUL	48	56	79	61	35	16.9	86
	APR-SEP	57	58	91	71	43	23	98
Tongue River Reservoir Inflow (2)	APR-JUL	110	57	220	154	66	0.40	193
	APR-SEP	125	58	240	172	78	9.3	215
NF Powder R nr Hazelton	APR-JUL	6.5	71	9.7	7.8	5.2	3.3	9.1
	APR-SEP	7.1	72	10.4	8.5	5.7	3.8	9.9
Powder R at Moorhead	APR-JUL	82	46	196	128	35	1.00	177
	APR-SEP	98	50	215	146	51	1.00	196
Powder R nr Locate	APR-JUL	90	45	225	145	36	1.00	199
	APR-SEP	105	48	250	164	47	1.00	220

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

* Milk River median is for years 1980-2008 & marked "30%" is 25% exceedance and marked "70%" is 75% exceedance.